Megacities Carbon Project Overview

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collaborators from JPL, Caltech, Arizona State University, Penn State University, NIST, NOAA, UCLA, Lawrence Berkeley National Lab, Harvard University, California Air Resources Board, AQMD, Le Laboratoire des Sciences du Climat et l'Environnement, Scripps, Earth Networks, Resources for the Future, NASA GISS, Columbia University, Association de surveillance de la qualité de l'air en Île-de-France

All material contained herein is pre-decisional, for discussion only.

Outline

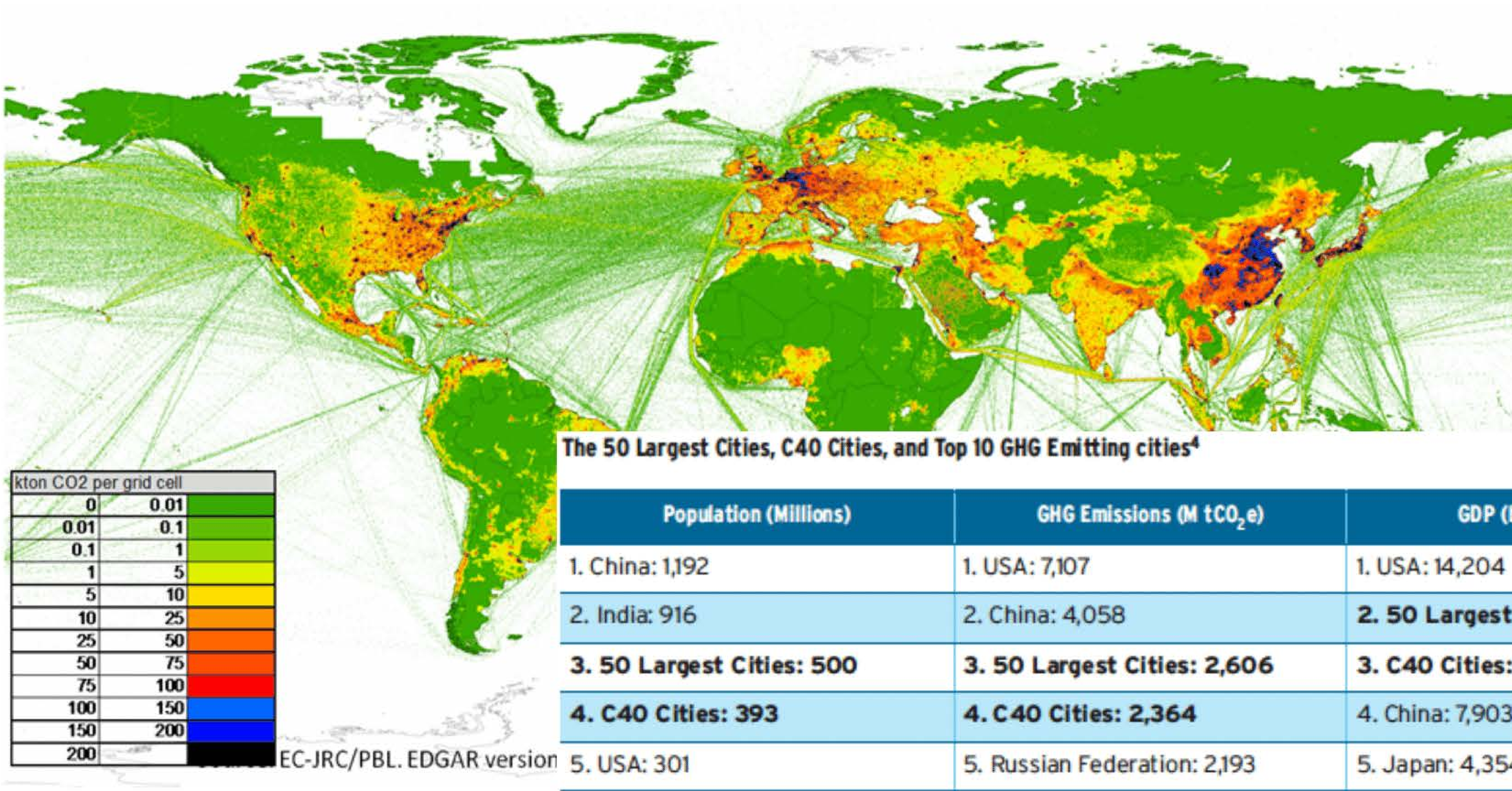
- History
- Motivation
- Project concept
  - Vision
  - Key elements
  - Notional architecture
- Opportunities & Challenges
- Topics and workshop approach

History

- 2008 1st Greenhouse Gas Information System workshop (**DOE/NOAA/NASA**)
- 2009 1st GHGIS/ICOS meeting (US/Europe) – megacities discussions start
- 2010
  - **NRC** report on greenhouse gas verification
  - **KISS** workshop on Quantifying Sources and Sinks of CO2
  - **NIST** GHG Quantification and Verification workshop
  - **NASA** Carbon Monitoring System (congressional mandate)
  - **CARB/NOAA** Calnex campaign
  - **ANR** MEGAPARIS project
- 2011
  - 1st & 2nd Megacities workshops (LA/JPL & Paris/AIRPARIF)
  - **NIST** INFLUX experiment (Indianapolis)

Also, related studies by Wofsy et al in
Boston, Salt Lake City, etc

Relevance: Cities matter
75% of global fossil-fuel CO_2



The 50 Largest Cities, C40 Cities, and Top 10 GHG Emitting cities[4]

Population (Millions)	GHG Emissions (M tCO_2e)	GDP (billion $ PPP)
1. China: 1,192	1. USA: 7,107	1. USA: 14,204
2. India: 916	2. China: 4,058	**2. 50 Largest Cities: 9,564**
3. 50 Largest Cities: 500	**3. 50 Largest Cities: 2,606**	**3. C40 Cities: 8,781**
4. C40 Cities: 393	**4. C40 Cities: 2,364**	4. China: 7,903
5. USA: 301	5. Russian Federation: 2,193	5. Japan: 4,354
6. Indonesia: 190	6. Japan: 1,374	**6. Top 10 GHG Cities: 4,313**
7. Brazil: 159	**7. Top 10 GHG Cities: 1,367**	7. India: 3,388
8. Russian Federation: 142	8. India: 1,214	8. Germany: 2,925
9. Top 10 GHG Cities: 136	9. Germany: 956	9. Russian Federation: 2,288
10. Japan: 128	10. Canada: 747	10. United Kingdom: 2,176

Source: *Cities and Climate Change: an urgent agenda*, World Bank, 2010

50 largest cities, 2005.

Urgency: cities are undergoing rapid change

http://live.c40cities.org/

- Both with **Stabilization**
  - Green LA Plan (2007)
    - 35% (vs 1990) by 2030
  - Paris Climate Plan (2007)
    - 25% (vs 2004) by 2020

and **Growth**

- Global urbanization will ***double*** by 2050
- Explosive growth in developing megacities

population >4%/year
emissions >10%/year

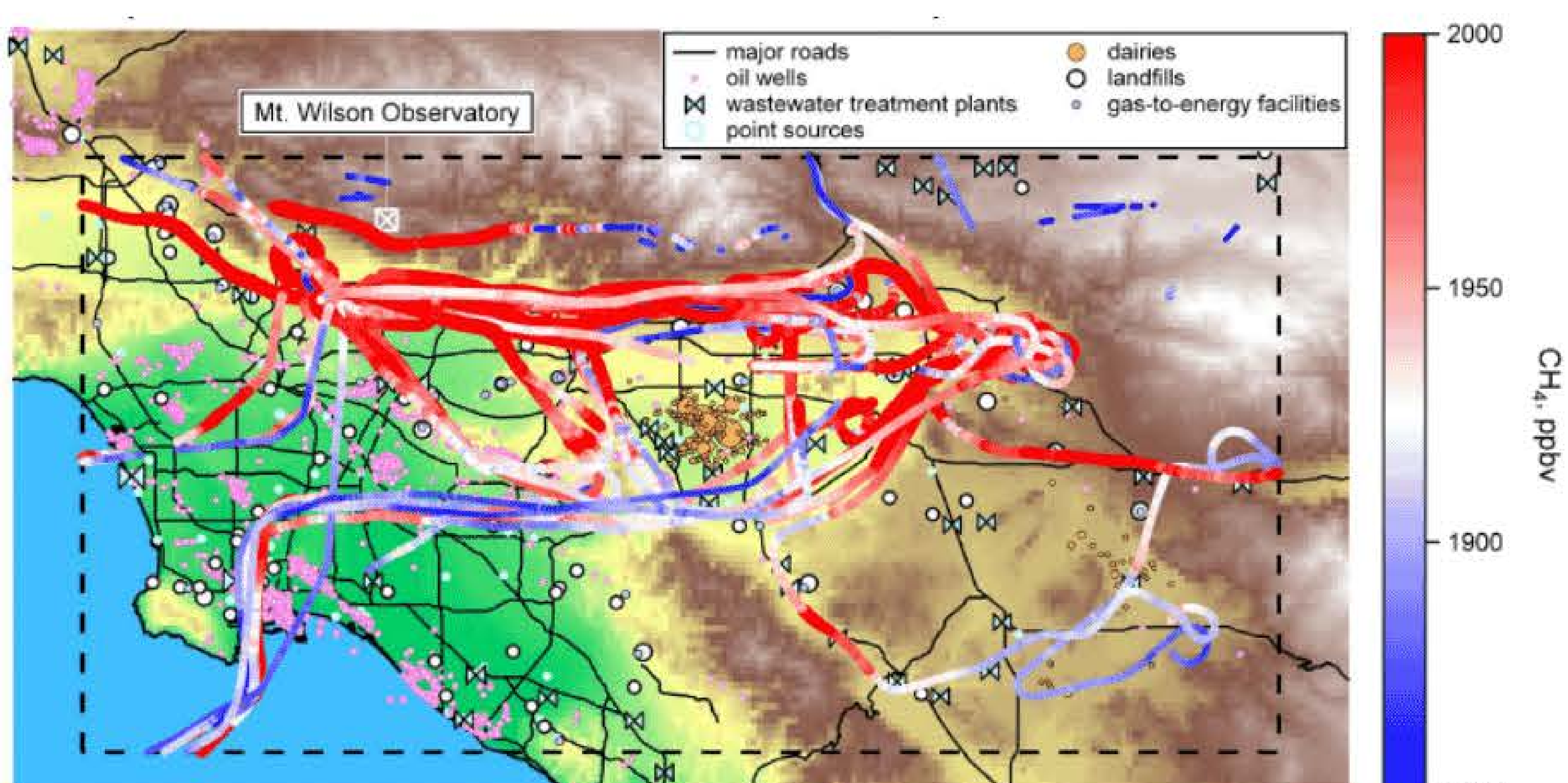
Pragmatism:
measuring CO_2 from cities is more tractable than countries

CO_2 at local scales is more intense than at larger scales

Right: Gridded annual fossil fuel CO2 emissions from a medium-size city (Indianapolis) show distinct gradients at different spatial scales. Right: CDIAC 2006 emissions for the CONUS plotted on a 1° (~100 km) show avg flux 200-600 gC/m2/yr. Middle: Vulcan 2002 emissions for the ~10,000 km2 area centered on Indianapolis on a 10 km grid. Left: Hestia 2002 emissions for the urban core on a 1 km grid. The Vulcan and Hestia plots use log-normal scales (typically >20,000 gC/m2/yr).

CH_4 is also important

June 1 (Bloomberg) -- Former U.S. President Bill Clinton urged cities and the World Bank to work on curbing methane emissions from landfills and charcoal, saying those steps first would buy time in the fight against global warming. Politicians may need years to work out a way to limit the carbon dioxide produced by burning fossil fuels, and it would cheaper and quicker to focus on other gases first, Clinton said at the C40 meeting of mayors from the world's largest cities in Sao Paulo today. Methane has 25 times the global warming impact of carbon dioxide…



Peischel et al 2010, Calnex, LA CH4

Hsu et al Atmo Environ, 2010

Comparison of estimated LA County anthropogenic CH_4 inventories.

Methods	MMT CO_2 E year^{-1}	Notes
CH_4 to CO scaling measured at Mt. Wilson	4.2 ± 0.12[a]	Estimate
CARB CH_4 inventory	3.0	IPCC methods

[a] Note that the estimated CH_4 emissions uncertainty reflects only the error in the slope determination from the regression between CH_4 and CO mixing ratios. Additional uncertainty due to LA County CO emissions should be considered (see Equation (2)); however, this value is currently not available.

See also:

Wunch, D., P. O. Wennberg, G. C. Toon, G. Keppel-Aleks, and Y. G. Yavin (2009), Emissions of greenhouse gases from a North American megacity, Geophys. Res. Lett., 36, L15810, doi:10.1029/2009GL039825.

Townsend-Small, A., S.C. Tyler, D.E. Pataki, X.Xu, L. E. Christensen, Isotopic measurements of atmospheric methane in Los Angeles, California, USA: Influence of "fugitive" fossil fuel emissions *J. Geophys Res* 117, D07308, doi:10.1029/2011JD016826, 2012

Kuc, T.; Rozanski, K.; Zimnoch, M.; Necki, J. M.; Korus, A. Anthropogenic emissions of CO2 and CH4 in an urban environment, *Appl. Energy* 2003, 75 (3-4), 193–203.

Challenges

- The ultimate impacts of local mitigation actions cannot yet be verified
  - Inventories of GHGs provide bottom-up estimates based on activity data
  - *Reported* annual uncertainties range from modest (5%) to large (>50%)
  - No direct attribution of atmospheric CO_2 or CH_4 to a given entity

- Over the time-span of emission policies (10+ years), these uncertainties can exceed the expected ***trend*** (10's of %)

- In the absence of better measures, we don't know if our actions are adequate or cost-effective

- Better data and modeling have the potential to improve the measures that tell us if our local actions are making a difference

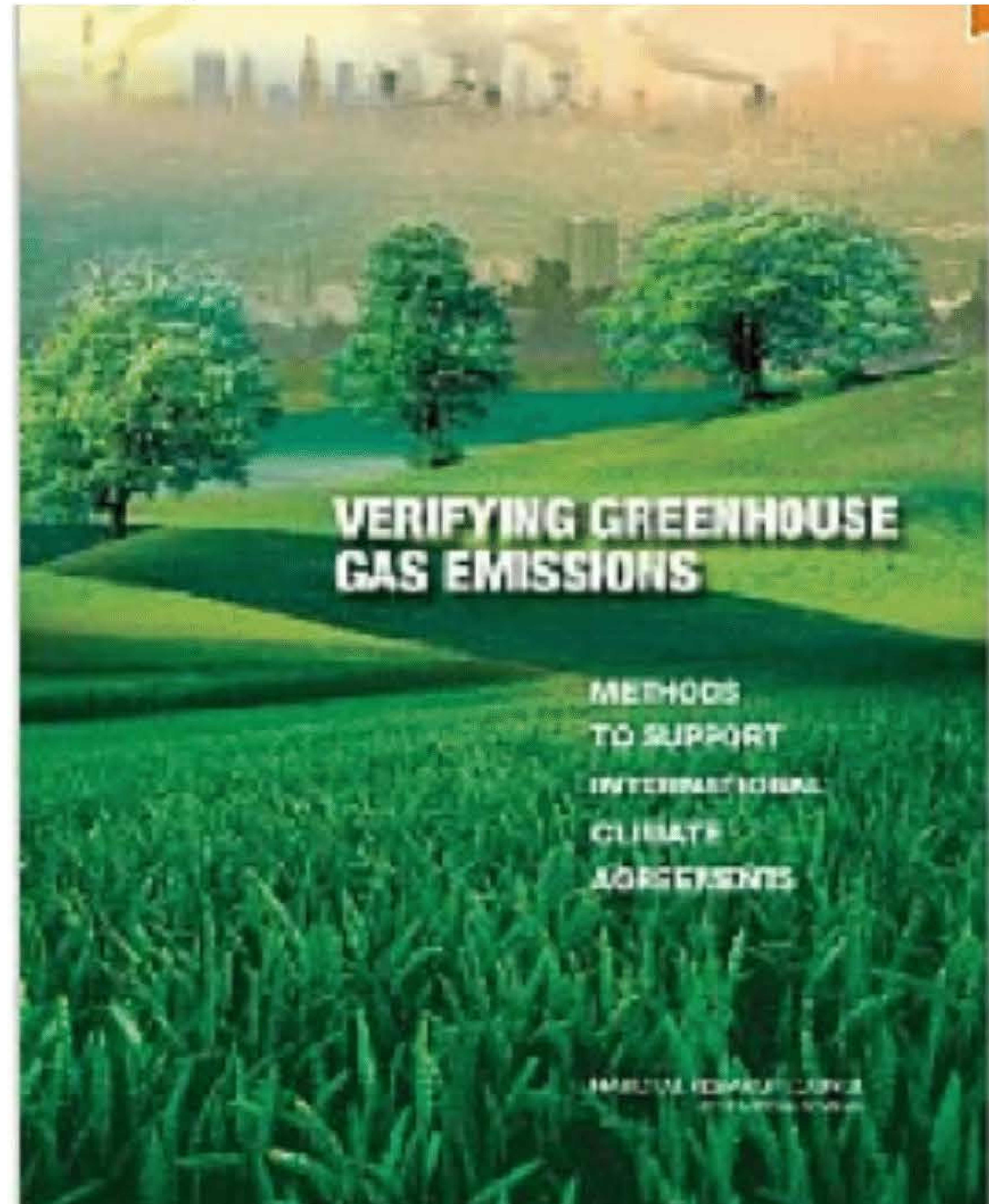
- However, we are still grounded in exploratory science mode
  - Methodological studies have not yet addressed complex megacities
  - Evolving capability in instrumentation (surface, air, and satellites)
  - Perhaps 20 years away from transition to an operational capability at this rate

The U.S. National Research Council recognized the need to focus on urban domes

(NRC, Pacala et al 2010)

“Recommendation. **Extend** the international atmospheric sampling network: To research the **atmospheric domes** of greenhouse gases over a representative sample of **large local emitters, such as cities** and power plants,

This research initiative would yield data needed to **calibrate satellite measurements of large local emitters**, demonstrate **an independent capability to monitor large local emitters from ground stations and aircraft**, and **document long-term shifts** in fossil- versus non-fossil-fuel sources in urban and industrial regions. An **initial goal** could be to deploy instruments at a **statistical sample of large emitters (e.g., 5-10).**



Our concept starts with LA, Paris, and TBD 3rd city in South America or Asia - and is designed to be expandable

Megacities Carbon Project

- A global monitoring system for urban CO_2 and CH_4 will offer actionable information to attribute and evaluate the effects of climate policies
  - *IF* the measurements and analytical methods can be shown to be accurate and cost-effective
  - *IF* they can work reliably in complex "emissions environments" (megacities)

- Ultimately, an operational system could consist of:
  - High accuracy surface measurements in 20+ representative megacities
  - Dense satellite observations of <u>all</u> major cities & other localized sources
  - Improved bottom-up emissions modeling
  - Analysis to integrate top-down & bottom-up data → connecting trends with action

- An international pilot project can bridge between today's methodological studies and that future operational system (initially 3 cities, but expandable)
  - Sustained (5+ yr) monitoring to detect trends in emissions
  - Demonstrate confidence in mitigation actions by validating their effects
  - Build technical and scientific capacity (infrastructure and knowledge)
  - Transparent data sharing and comparison to promote confidence and trust

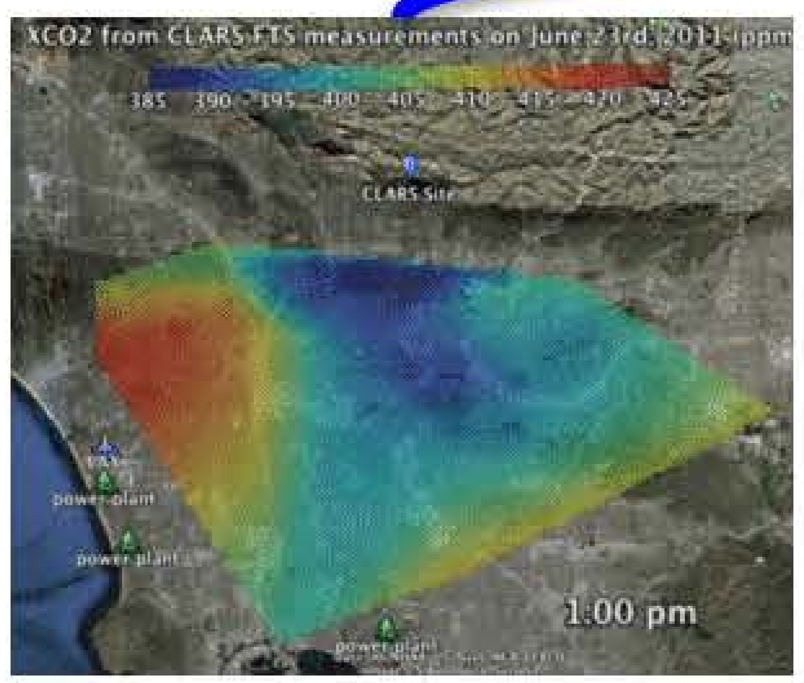
All resting on scientific principles and credibility

Vision: towards an operational monitoring system

2010

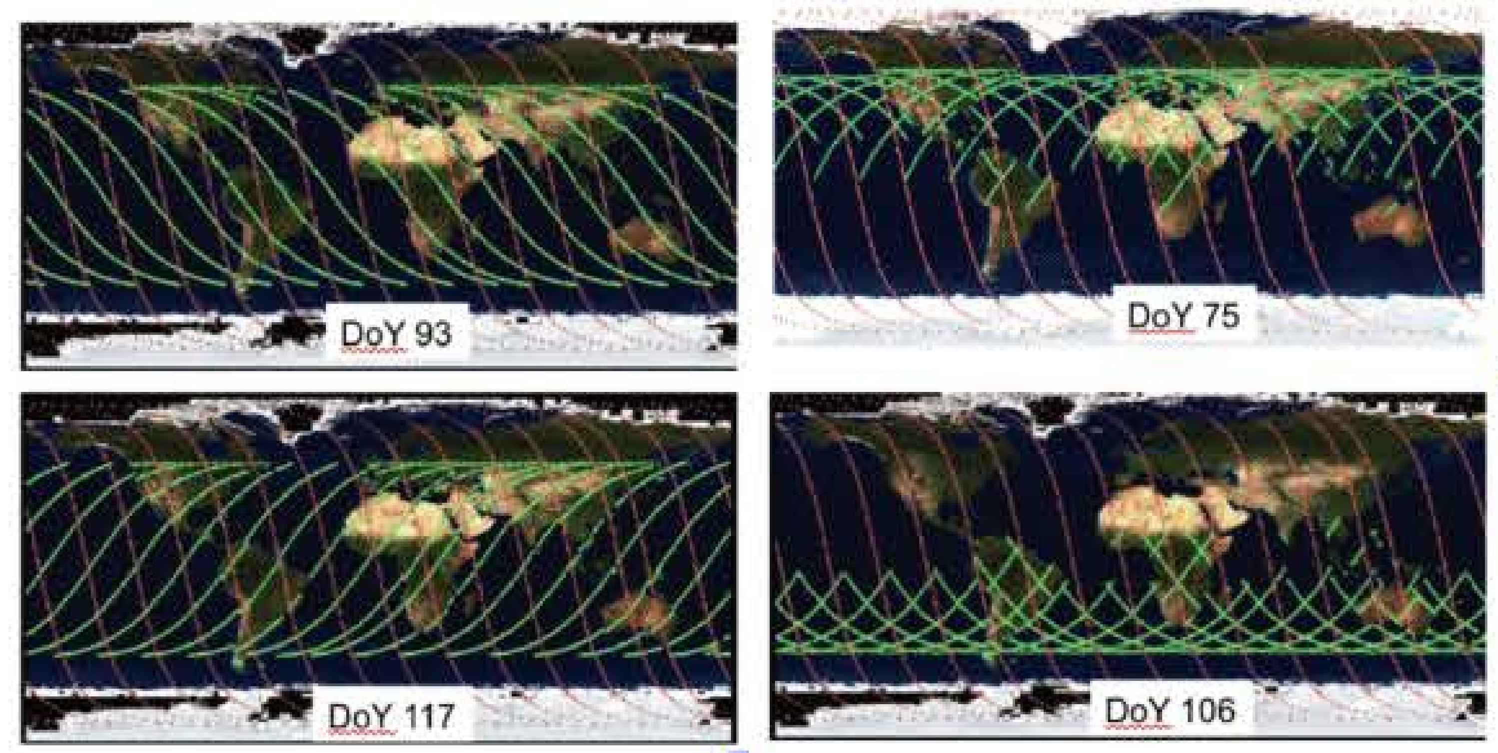
2015

2020



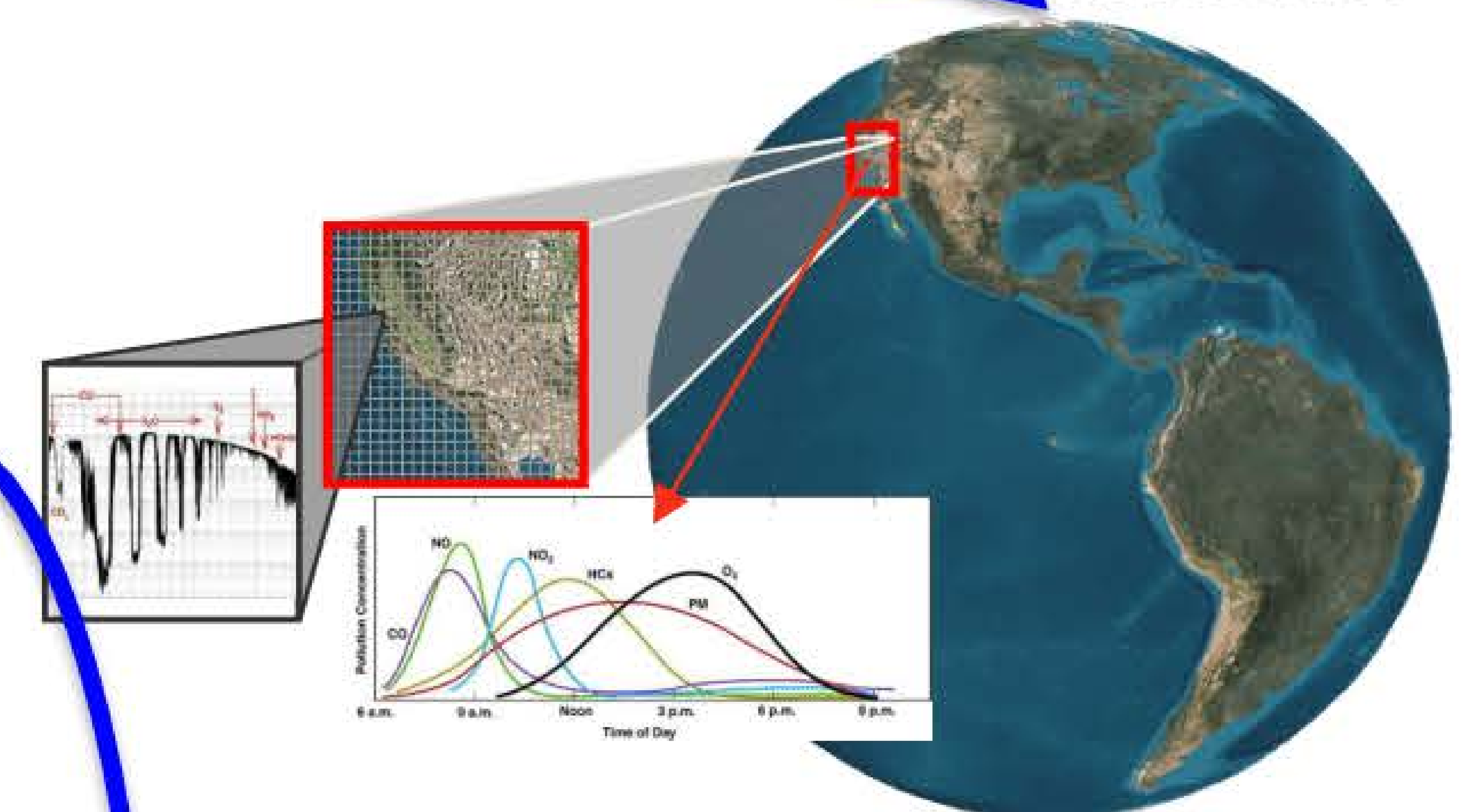
Existing surface networks in LA, Paris, ...

Near-term Satellites

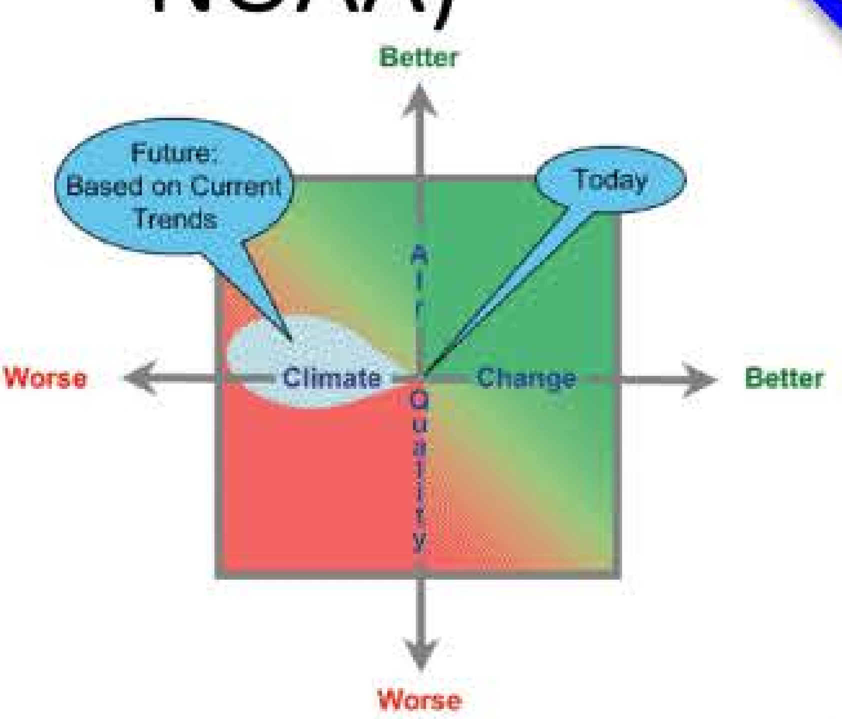


CMS (NASA)

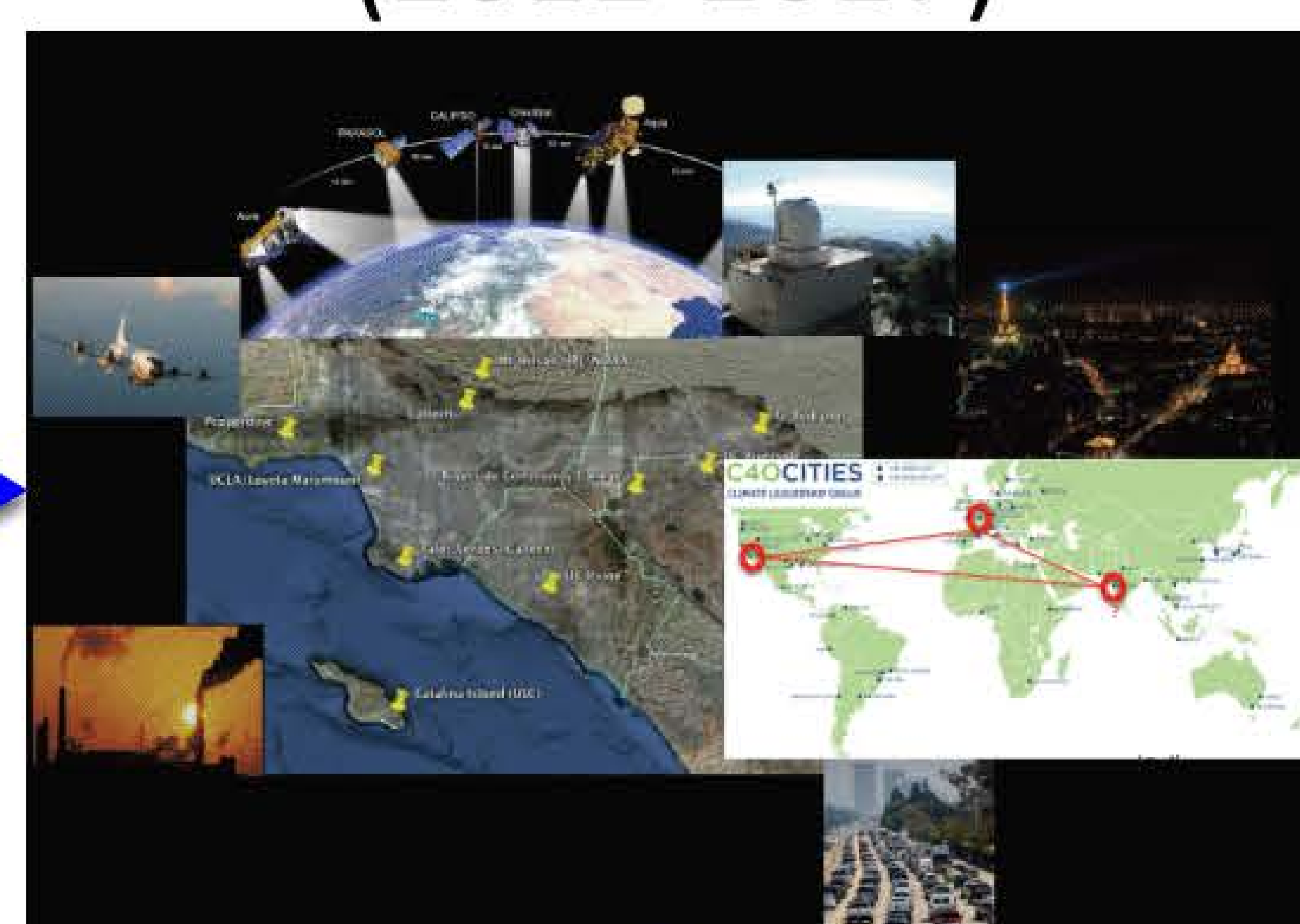
Next generation satellites



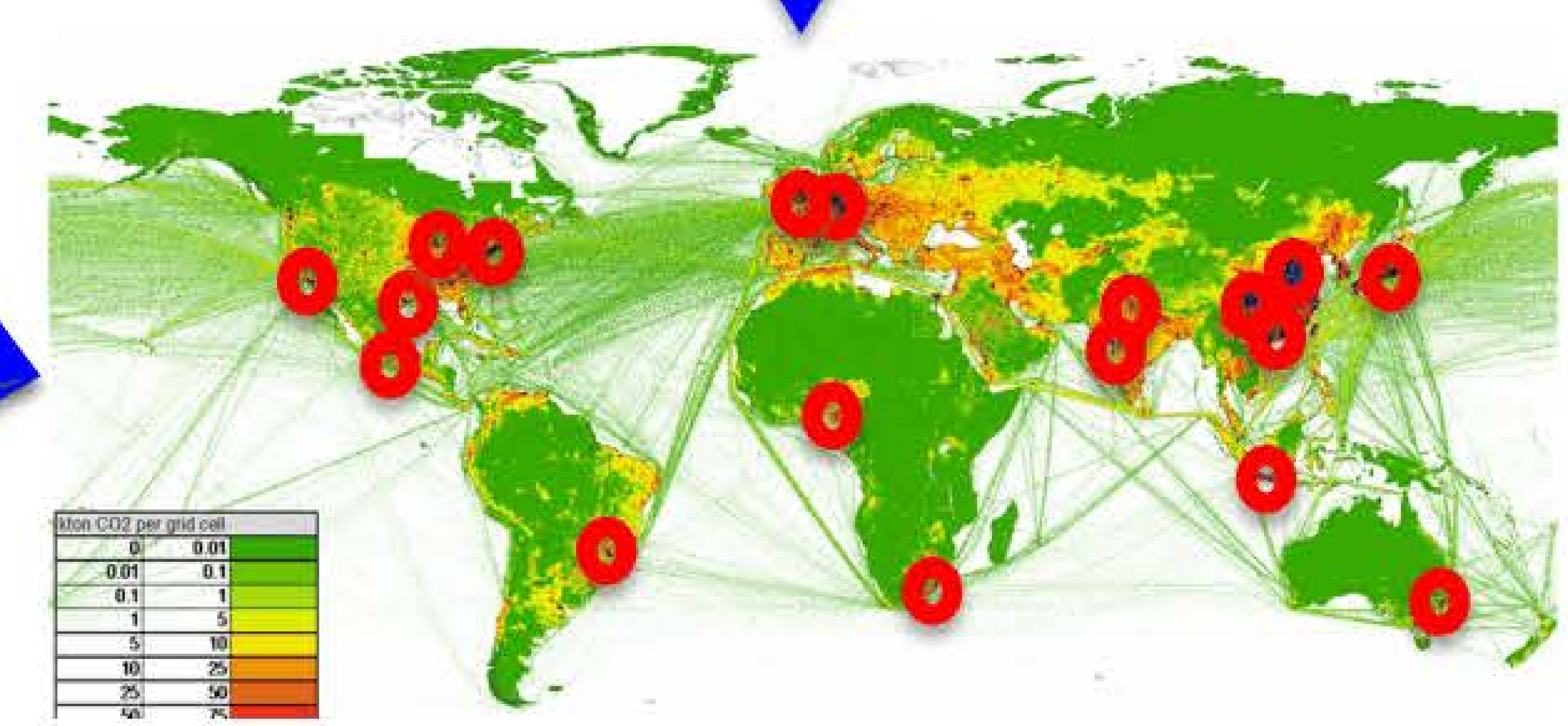
Calnex (CARB/ NOAA)



Megacities Carbon Pilot (2012-2017)



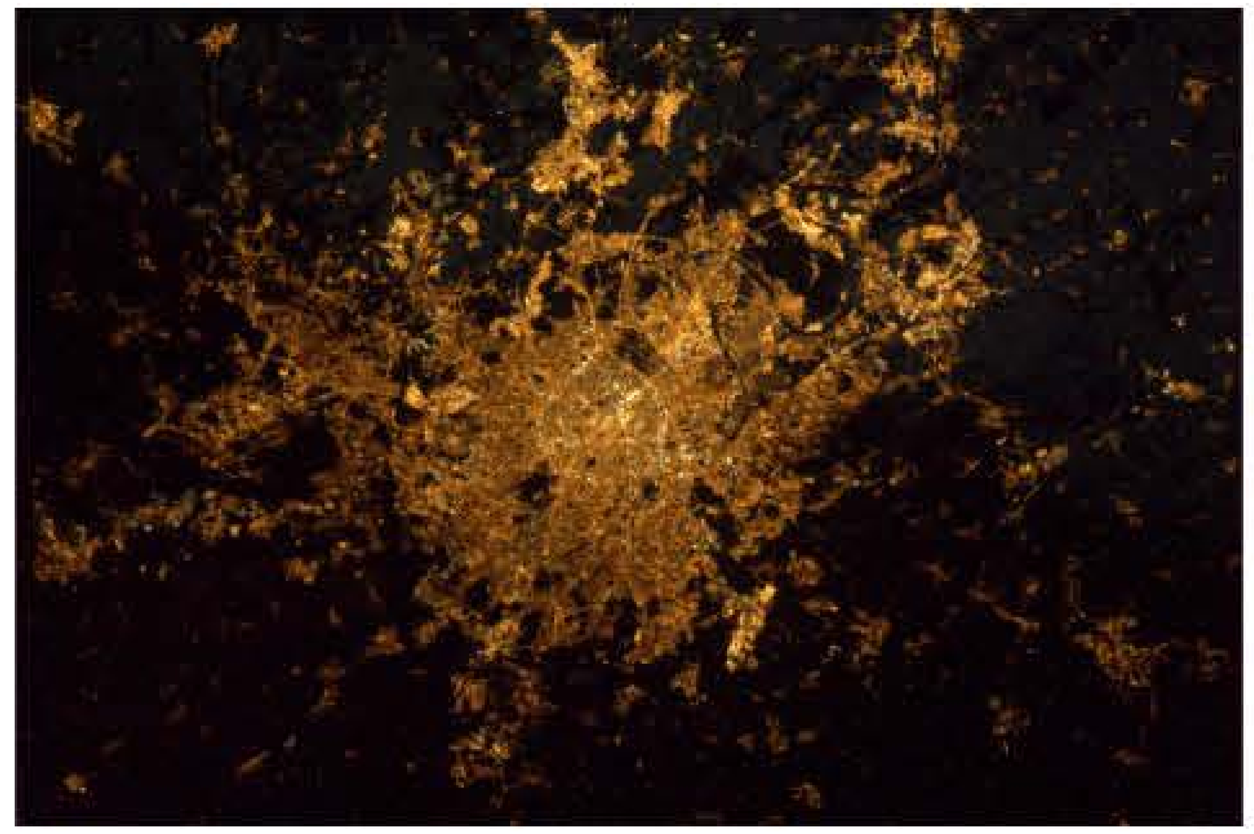
Global Urban Monitoring System



INFLUX (NIST)

A few carefully selected megacities

Los Angeles



Paris

Sao Paulo (TBD)

Beijing/Tianjin (TBD)

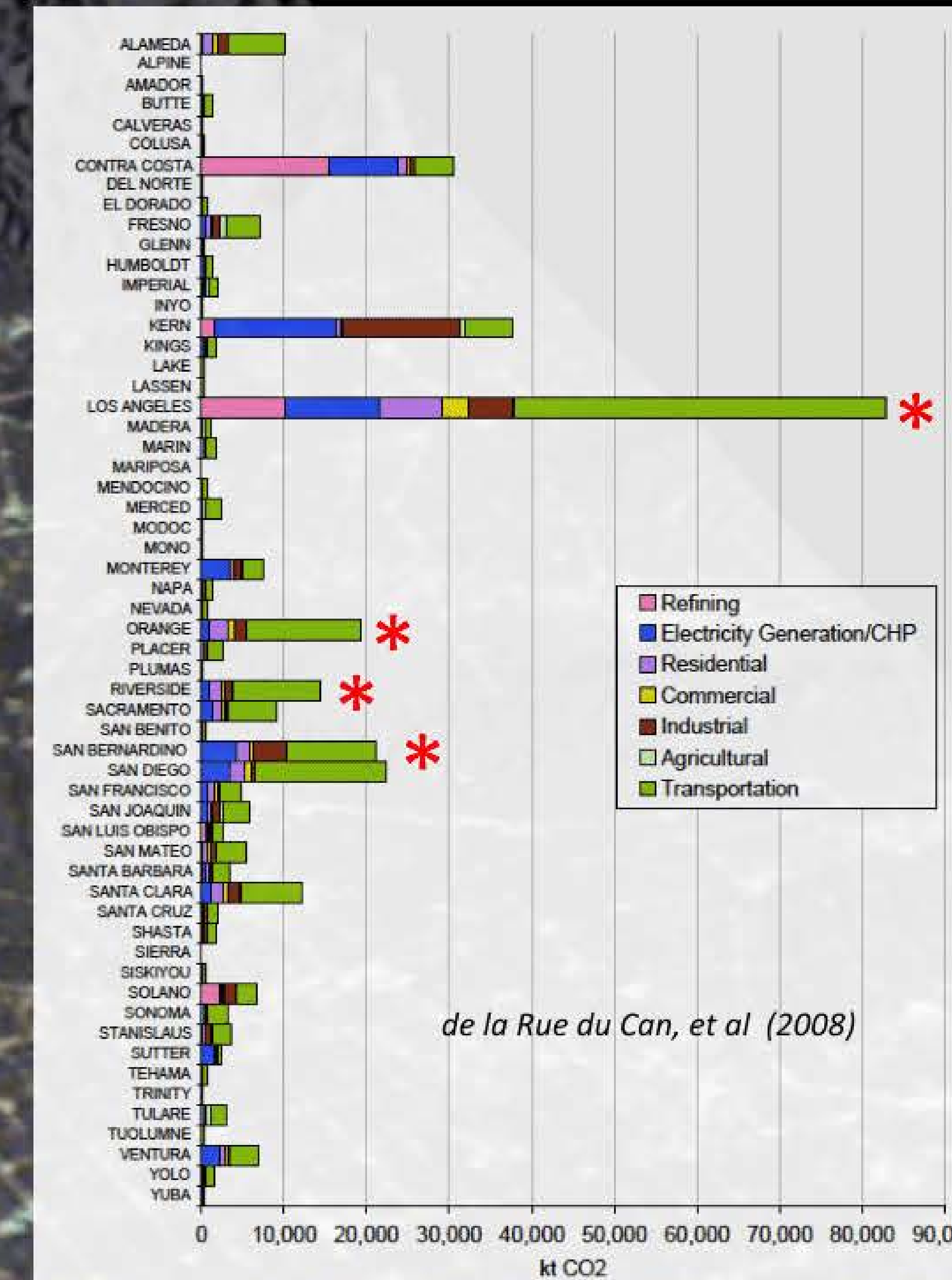
A first step toward forming an international pilot project to:

- Expand the science base necessary to support robust, reliable, and effective GHG determinations for cities,
- Advance the necessary measurement capabilities and scientific knowledge through contributions from all participants,
- Move toward international recognition of standard methodologies to measure and characterize urban GHG domes and quantify their dynamics, and
- Assure those charged with forming GHG mitigation policies globally that a means is available to quantify the performance of those policies.

While being wary of expanding too quickly (walk then run);
More on this tomorrow....

Why Los Angeles?

- Textbook megacity
  - LA county: #1 CO_2 emitter in US (tied with Harris County, TX)
  - LA megacity (SCAB) is largest CO_2 emitter in California(*)
  - Large transportation section
  - Largest seaport in the US
  - 1/3 of the state's CH_4 emissions from landfills
  - Significant natural gas infrastructure
  - Complex meteorology & geography



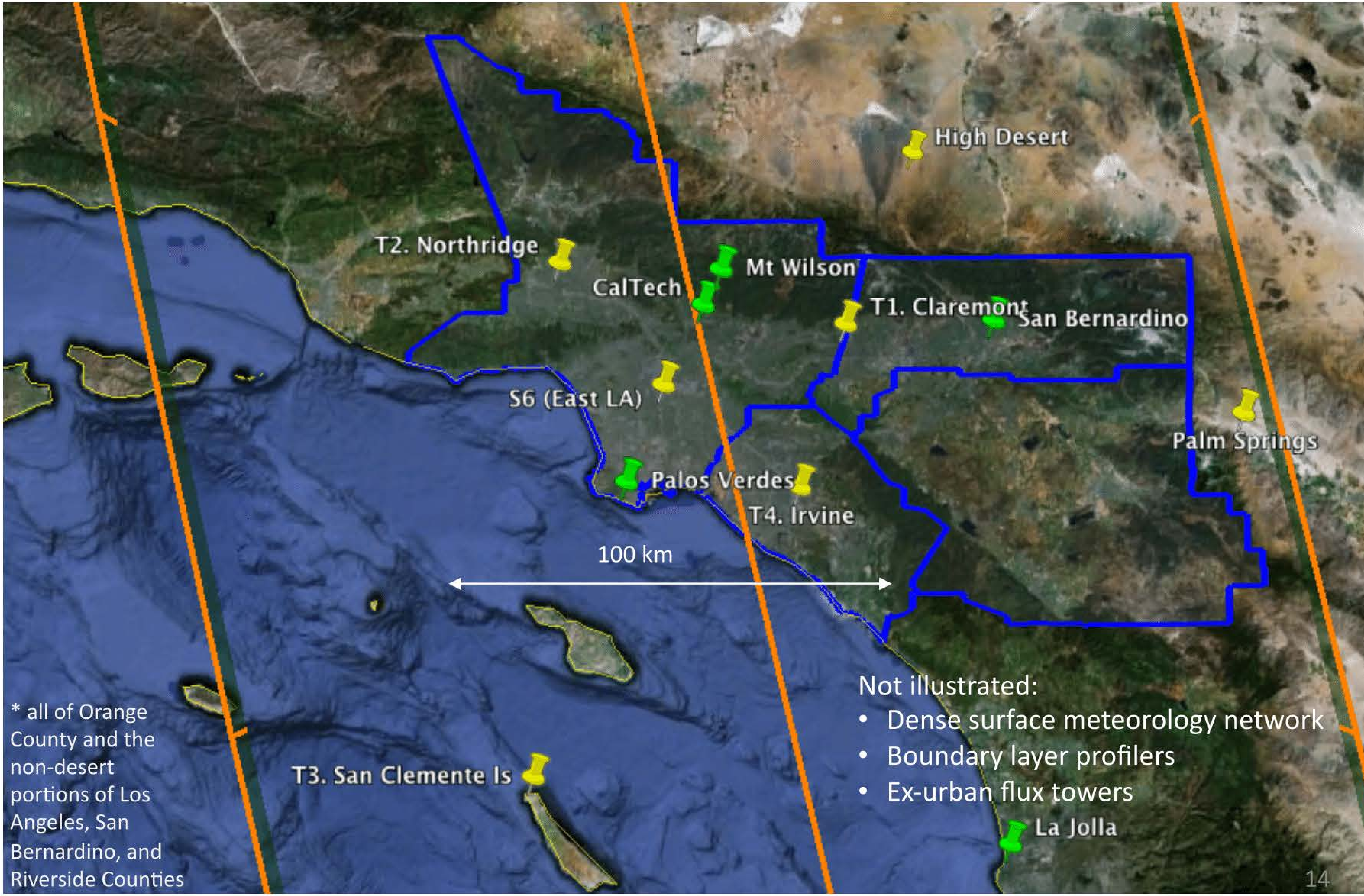
- Established observational network (Caltech, Mt. Wilson, Palos Verdes)

- Critical mass of local research institutes (JPL, Caltech, UCLA, UCI, UCR)

- Climate policy leadership (LA Mayor's Office, CARB)

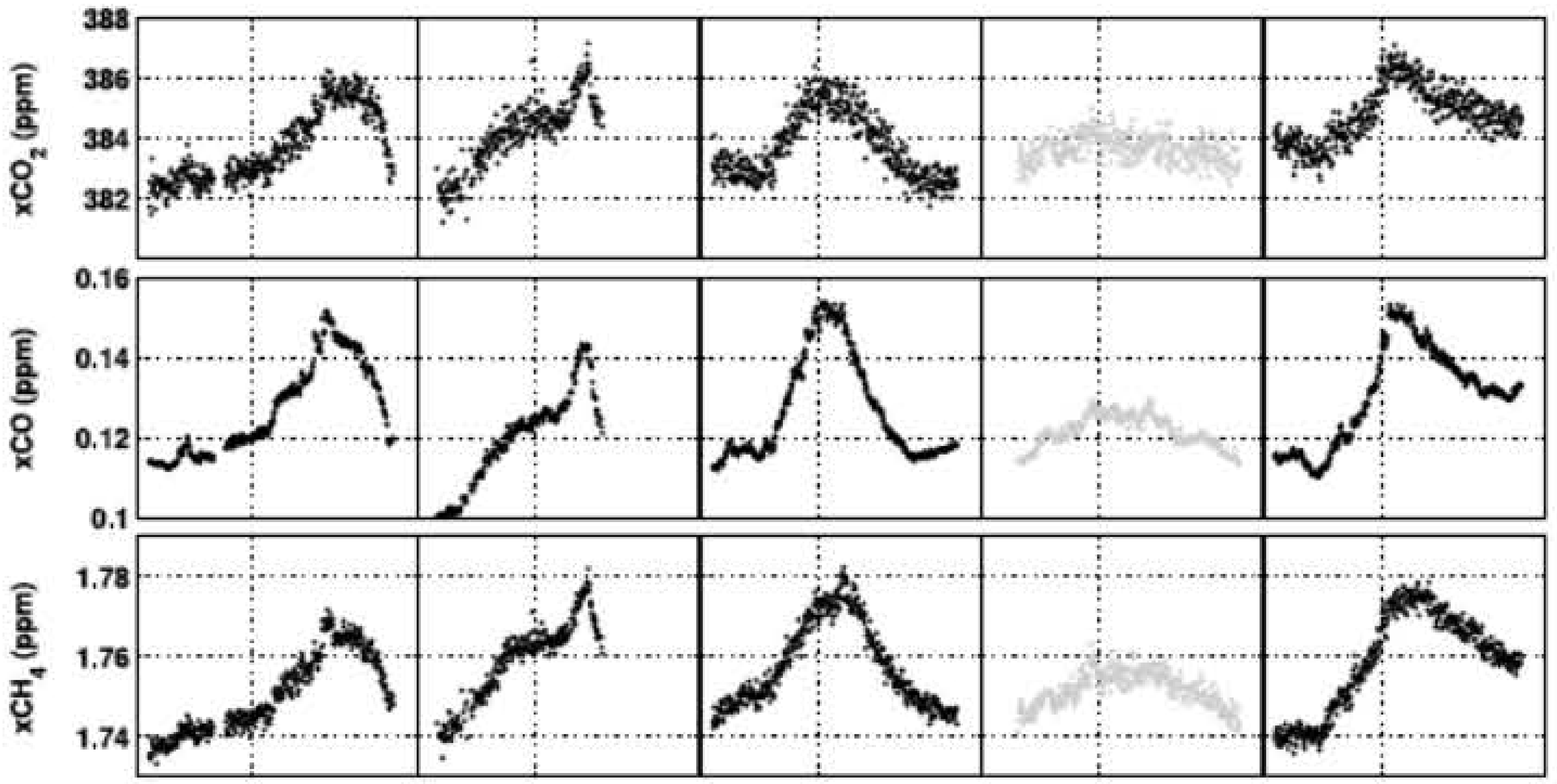
Notional LA Megacity Observing Network

Existing/planned GHG station | New GHG stations | OCO-2 ground track | Megacity Domain (South Coast Air Basin*)



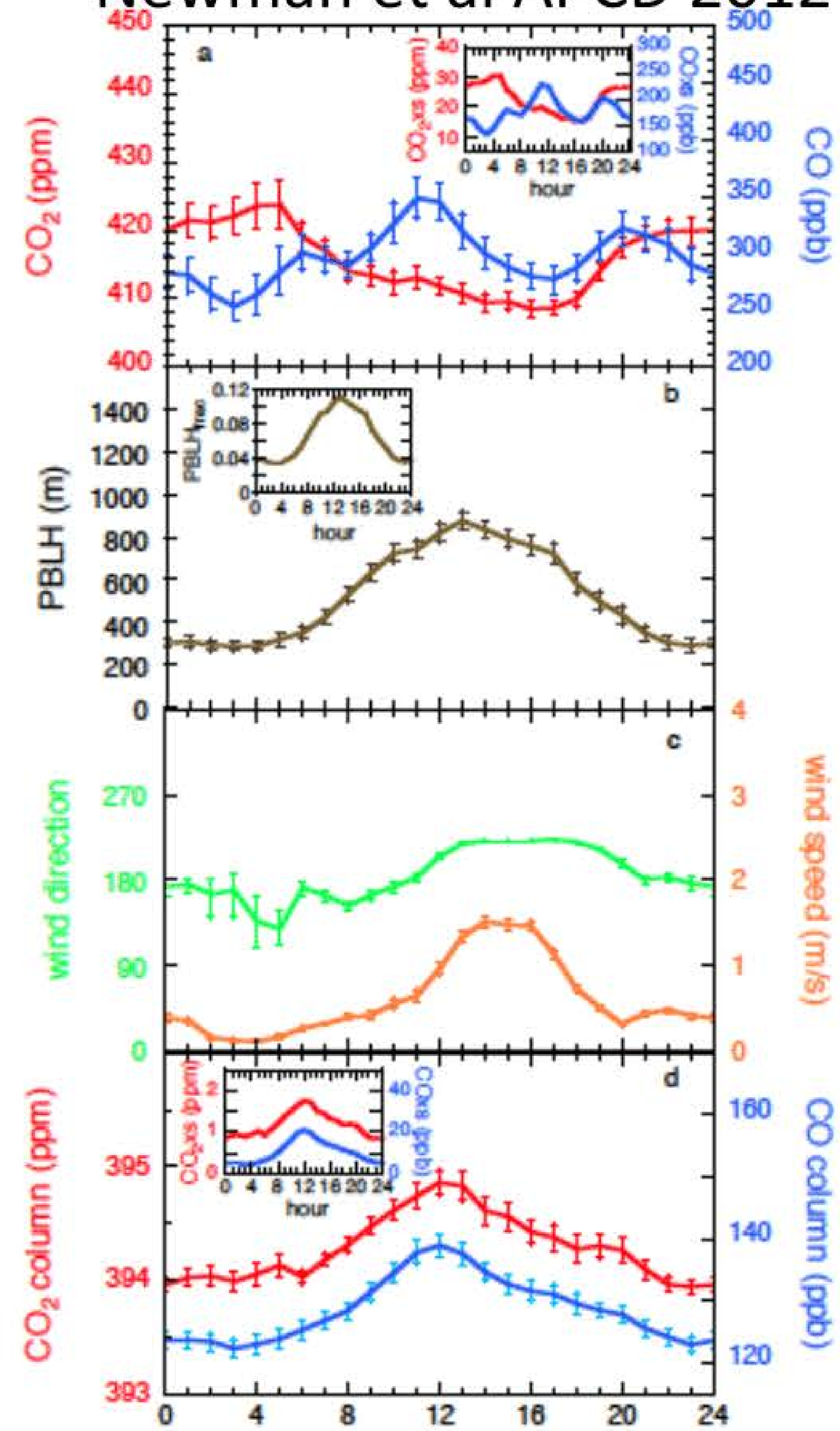
Preliminary and pre-decisional

Key observational elements



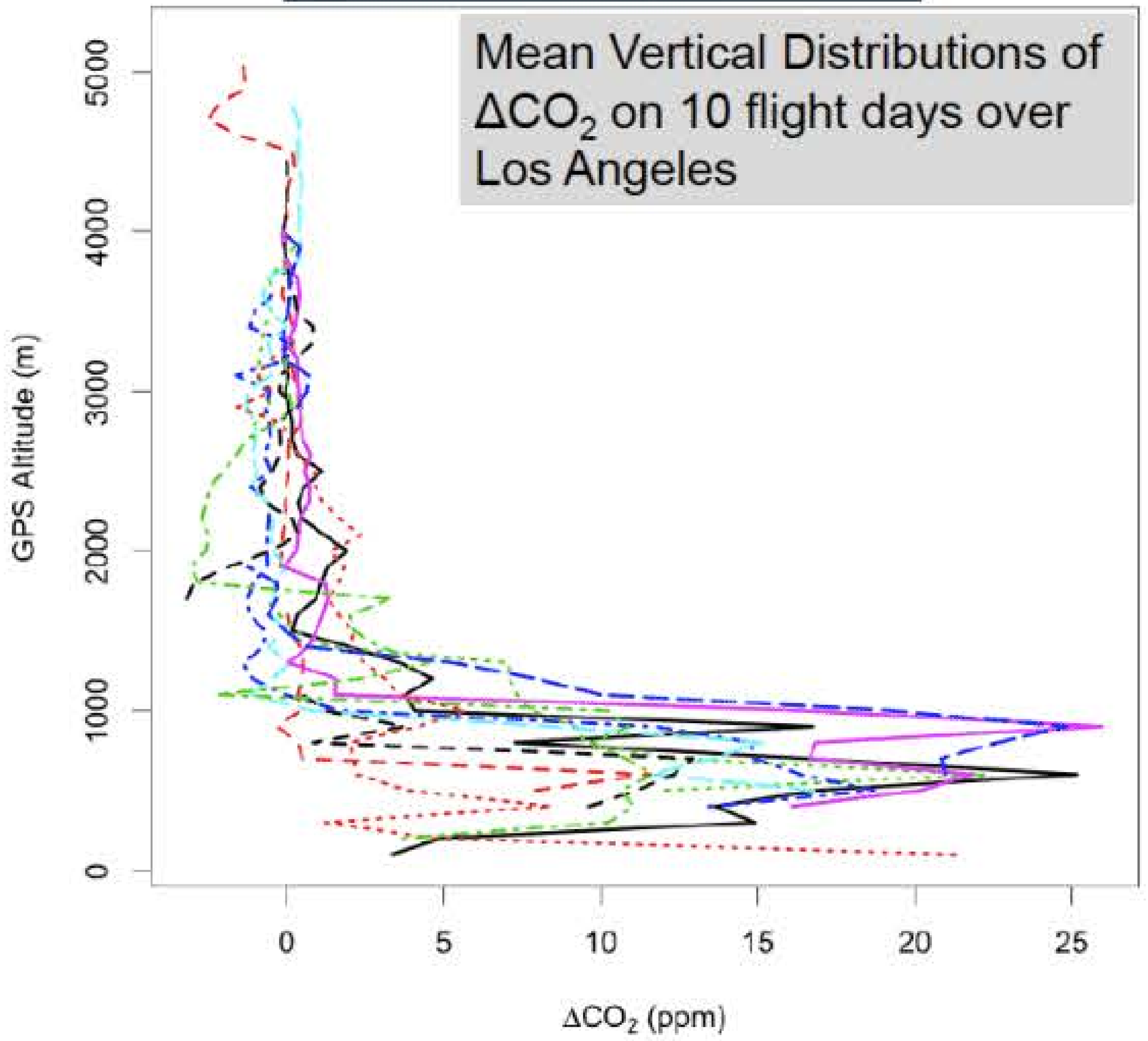
Fixed column observations, Wunch et al, GRL, 2009

In-situ sensors and flasks
Calnex results, Pasadena,
Newman et al APCD 2012

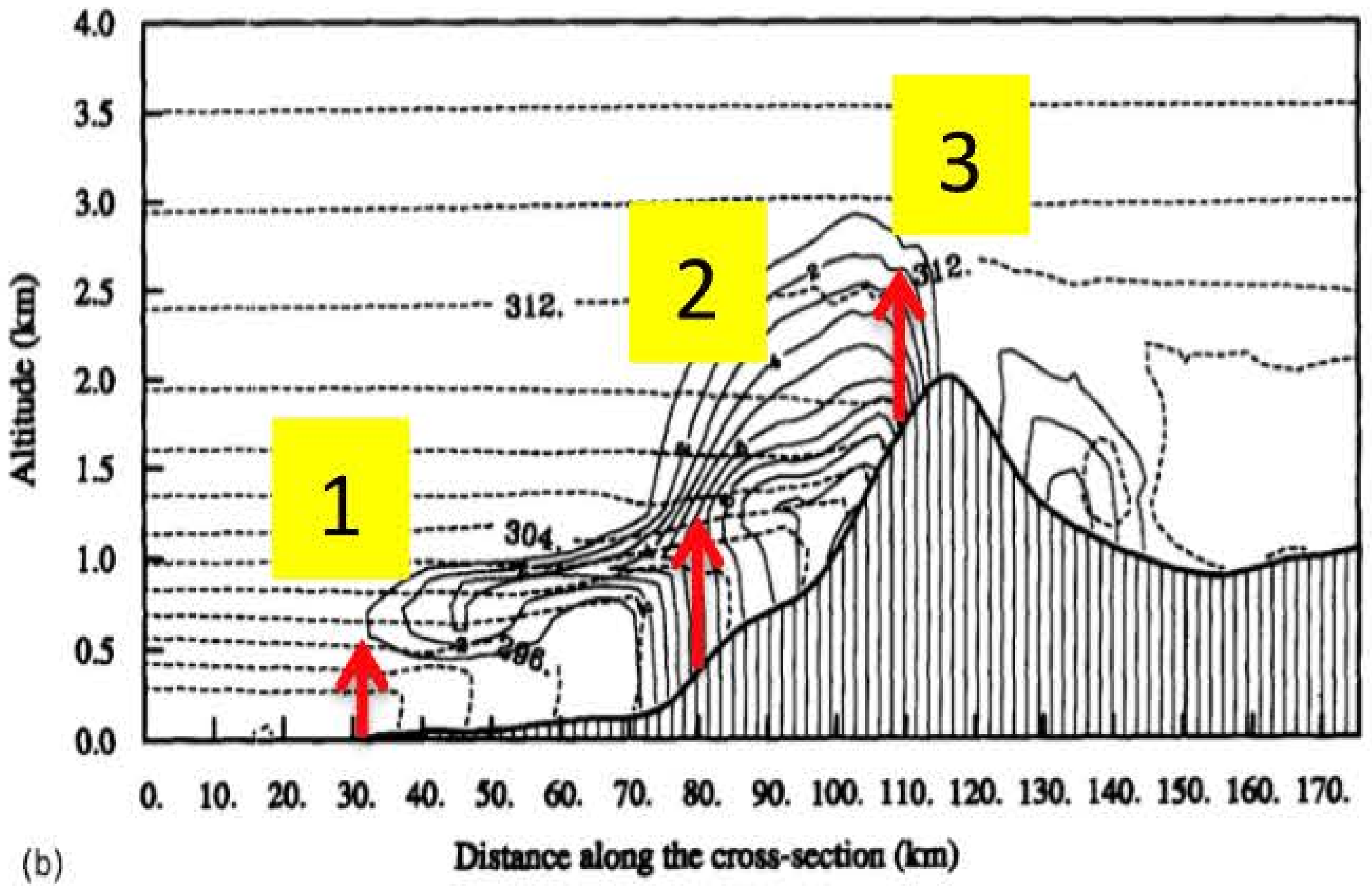


Scanning partial column observations from Mt. Wilson (CLARS, Sander et al)

Airborne observations
(Calnex, Wofsy et al 2010)

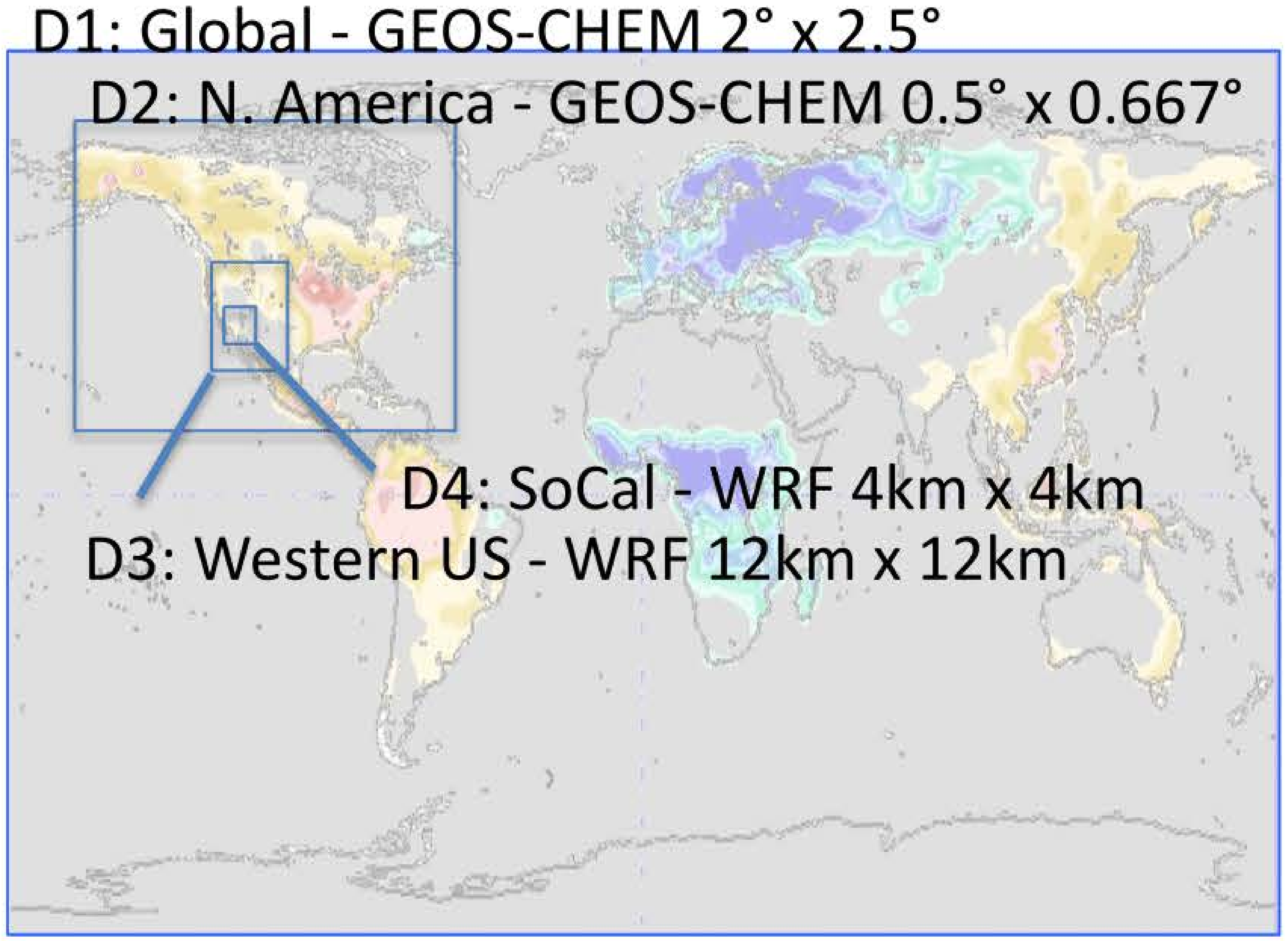


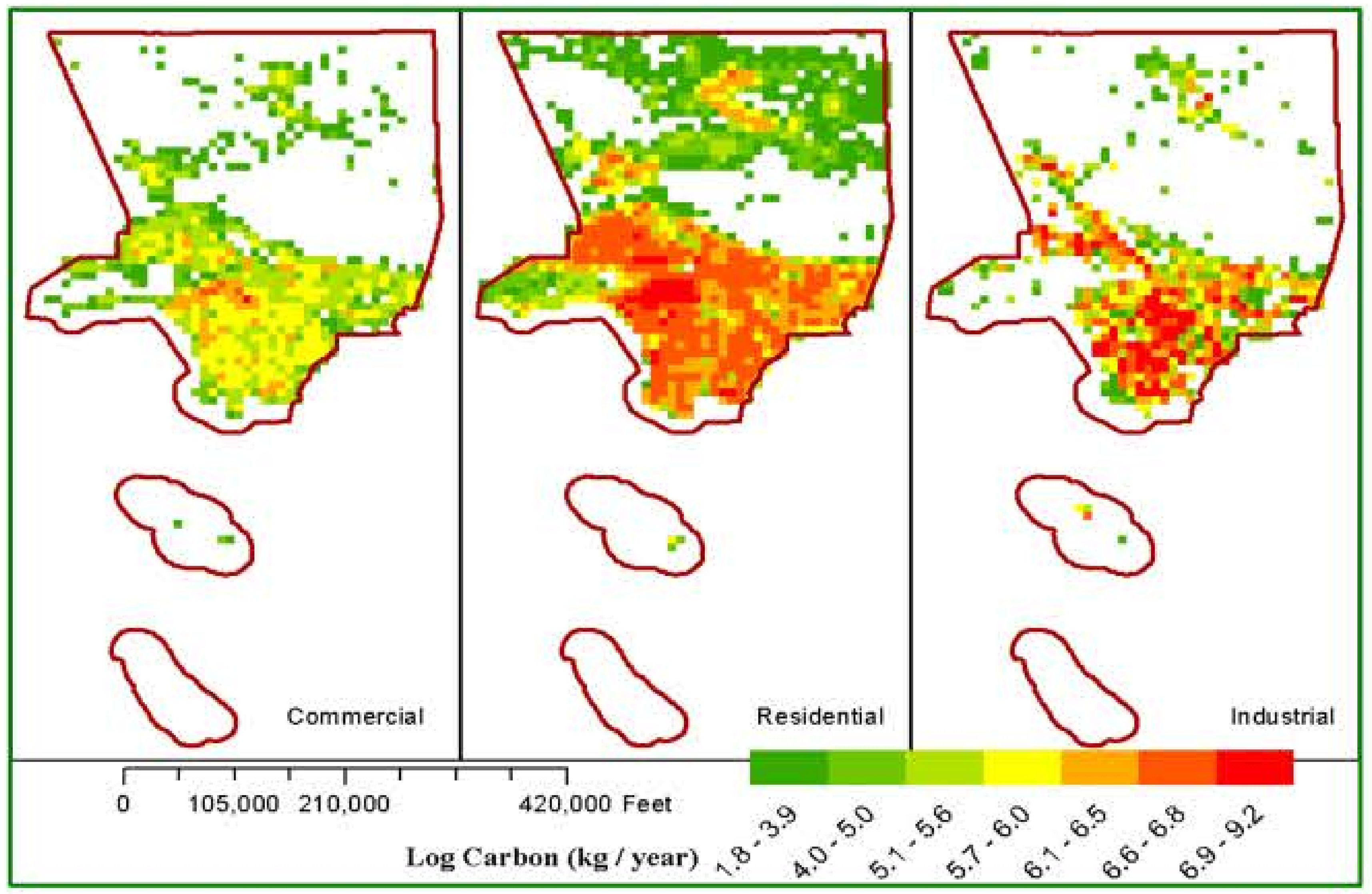
Boundary layer & surface met
(after Lu and Turco 1995)



Other key elements

- Nested tracer transport models
- Observations of boundary conditions
- Space-time resolved CO_2 and CH_4 emission data products (Vulcan/Hestia, etc)
- Data QC, calibration meta-data, uncertainty quantification
- Attribution and trend analysis
- Validation
- Data sharing and stewardship
- Sustained engagement with stakeholders





Gurney et al, Gridded (2500m X 2500m) CO_2 emissions

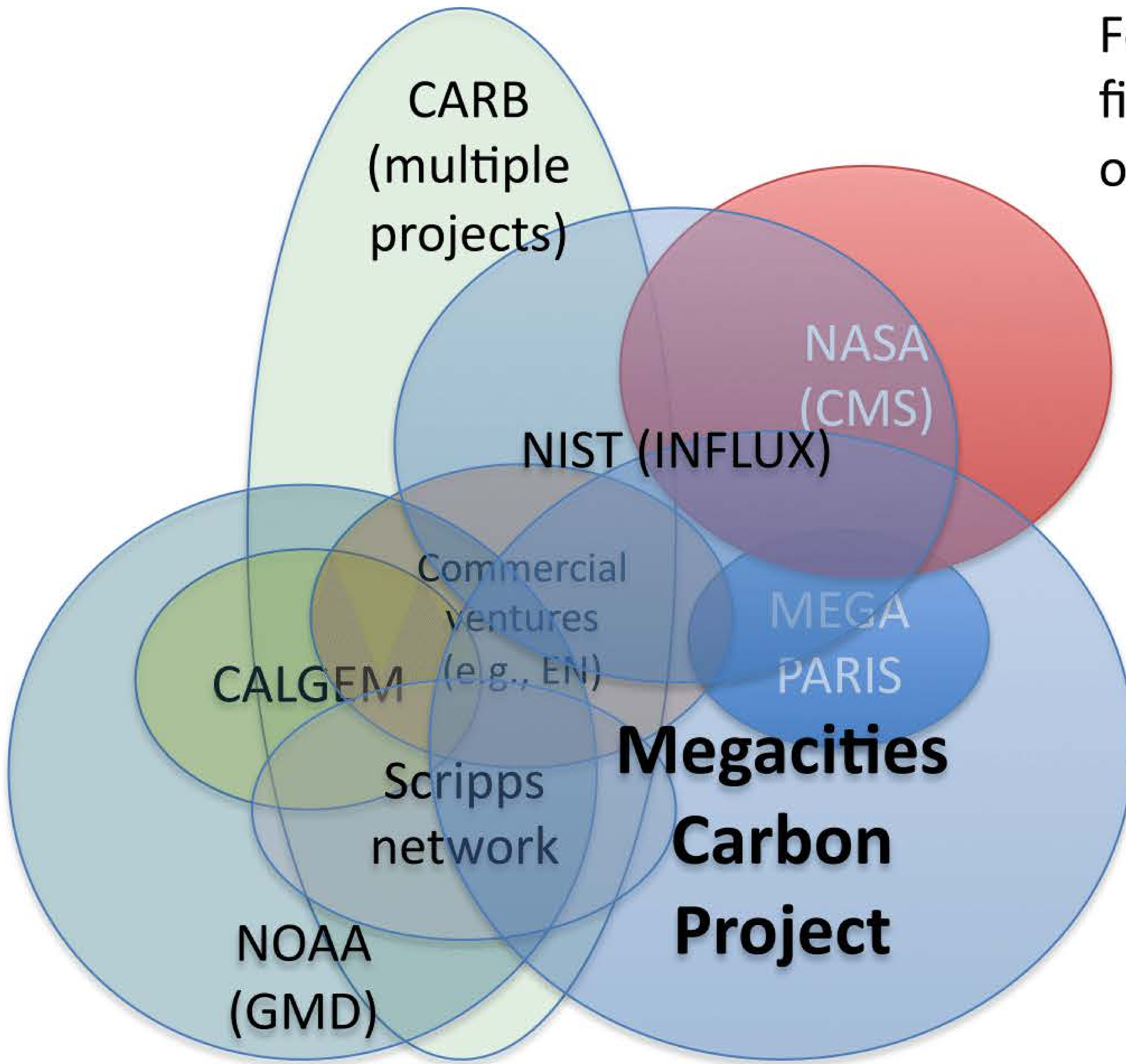
Putting it all together

(notional system architecture)

Towards well-posed questions

Opportunity/Complexity
overlapping interests and capability

For illustration only; figure is not complete; overlap is notional



Challenges

- Relevant and responsive to stakeholder needs
- Credibility in the face of relentless scrutiny
  - Transparent (data, models, meta-data, UQ, protocols)
  - Traceable and calibrated
  - Validated
- Sustained commitment (multi-year trends)
  - Continuity of critical observations
  - Guaranteed access to data

Topics for workshop

- Project Objectives
- Needs for trace gas observations
  - Fixed network: How many, locations, which species
  - Intensive campaigns (surface mobile and airborne)
  - Satellite observations
- Needs for ABL and surface met observations
- Needs for data QC, calibration, & data stewardship
- Needs for modeling
- Analysis (attribution, trends, linking to actions)
- Validation
- Integration: bringing it all together
- Programmatics
  - Project policies: Data sharing, Releasing results/publication
  - Capacity building mechanisms
  - International framework for coordination
- Others?

For each topic, consider: how good is good enough? And are there city-unique needs? (quantitative where possible)